

## BOOSTER WITH SPRING TO ADAPT AIR SPRING PRESSURE FOR LOAD DEPENDENT SHOCK ABSORBER

### FIELD OF THE INVENTION

**[0001]** The present invention relates to frequency dependent damper s or shock absorbers, and more particularly to a booster to adapt air spring pressure for a load dependent shock absorber.

### BACKGROUND OF THE INVENTION

**[0002]** Shock absorbers are used in conjunction with automotive suspension systems to absorb unwanted vibrations which occur during driving. To absorb these unwanted vibrations, shock absorbers are generally connected between the sprung portion (body) and the unsprung portion (suspension) of the automobile. A piston is located within a pressure tube of the shock absorber and the pressure tube is normally attached to the unsprung portion of the vehicle. The piston is normally attached to the sprung portion of the vehicle through a piston rod which extends through the pressure tube. The piston divides the pressure tube into an upper working chamber and a lower working chamber. The shock absorber, by restricting fluid flow between the upper and lower working chambers, produces a damping force that counteracts the vibration that would otherwise be transmitted from the unsprung portion of the vehicle to the sprung portion of the vehicle.

**[0003]** Spring devices are implemented with the shock absorbers to resiliently support the vehicle on the suspension system. Exemplary spring

devices include coil springs, torsion bars and air springs. As the vehicle load increases the spring devices compress. The dampening capability of the shock absorbers, however, remains constant regardless of the vehicle load. While a constant dampening ability may be acceptable in some applications, other applications would benefit from a shock absorber whose dampening characteristics vary with vehicle load.

### SUMMARY OF THE INVENTION

**[0004]** Accordingly, the present invention provides a suspension system for a vehicle, which includes a shock absorber with variable dampening capability. The suspension system includes a frequency dependent damper (FDD) or shock absorber defining a first pressurized working chamber and an air spring assembly defining a second pressurized working chamber. A booster enables pressure communication between the first pressurized working chamber and the second pressurized working chamber. The booster includes a resilient member that effects booster performance.

**[0005]** In one feature, the booster includes a housing defining segmented chambers and a piston assembly slidably disposed within the segmented chambers.

**[0006]** In another feature, the piston assembly includes a first piston dividing a first segmented chamber and a second segmented chamber and a second piston interconnected with the first piston and dividing the second segmented chamber and a third segmented chamber. The first segmented

chamber is in fluid communication with the second pressurized working chamber and the third working chamber is in fluid communication with the first pressurized working chamber. The first piston is of a larger diameter than the second piston. The resilient member biases the first piston.

**[0007]** In still another feature, a restrictor is disposed between the air spring assembly and the booster to inhibit pressurized fluid flow therebetween.

**[0008]** In yet another feature, the booster includes a housing defining a chamber and a piston slidably disposed within the chamber to define segmented chambers. The resilient member biases said piston.

**[0009]** Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0010]** The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

**[0011]** Figure 1 is a perspective view of a vehicle having a suspension incorporating frequency dependent dampers according to the present invention;

**[0012]** Figure 2 is a cross-sectional side view of an integrated shock assembly including a frequency dependent damper and an air spring assembly;

**[0013]** Figure 3 is a schematic view of the suspension including the frequency dependent damper, air spring assembly and a booster according to the present invention; and

**[0014]** Figure 4 is a schematic view of the suspension including the frequency dependent damper, air spring assembly and an alternative booster according to the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0015]** The following description of the preferred embodiments is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

**[0016]** Referring now to Figure 1, a vehicle 10 includes a rear suspension system 12, a front suspension system 14 and a body 16. The rear suspension system 12 includes a pair of independent suspensions 18 supporting a pair of rear wheels 20. Each rear independent suspension 18 is attached to the body 16 by means of a frequency dependent damper or shock absorber 22 and an air spring assembly 24. Similarly, the front suspension system 14 includes a pair of independent suspensions 26 supporting a pair of front wheels 28. Each independent front suspension 26 is attached to the body 16 and includes an integrated shock assembly 30 having the shock absorber 22 and an air spring assembly 24.

**[0017]** The shock absorbers 22 dampen the relative movement of the unsprung portion (i.e., the front and rear suspension systems 12 and 14) of the

vehicle 10 with respect to the sprung portion (i.e., the body 16) of the vehicle 10. While the vehicle 10 has been depicted as a passenger vehicle having independent front and rear suspensions, the shock absorbers 22 and air spring assemblies 24 may be incorporated into other types of vehicles having other types of suspensions. It is also anticipated that the shock absorbers 22 and air spring assemblies 24 may be incorporated into other types of applications, including, but not limited to, vehicles having air springs, leaf springs, non-independent front and/or non-independent rear suspension systems. Further, the term "shock absorber" as used herein is meant to refer to dampers in general and thus includes MacPherson struts, spring seat units, as well as other shock absorber designs known in the art.

**[0018]** Referring now to Figure 2, the integrated shock assembly 30 is illustrated. The integrated shock assembly 30 includes the shock absorber 22 and the air spring assembly 24. The shock absorber 22 is disclosed in detail in commonly assigned U.S. Patent Application No. 09/778,455, filed February 7, 2001 and which is expressly incorporated herein by reference. The shock absorber 22 includes a pressure tube 32, a piston assembly 34, a piston rod 36 and a rod guide assembly 38. The pressure tube 32 defines a working chamber 40 that is filled with a gas, preferably air, at a specified pressure to act as the damping medium. The piston assembly 34 is slidably disposed within the working chamber 40 and divides the working chamber 40 into an upper working chamber 42 and a lower working chamber 44. A seal assembly 46 is disposed between the piston assembly 34 and the pressure tube 32 to enable sliding movement of

piston assembly 34 within the pressure tube 32 without generating undue frictional forces. The seal assembly 46 seals the upper working chamber 42 from the lower working chamber 44.

**[0019]** The piston rod 36 is attached to the piston assembly 34 and extends through the upper working chamber 42 and through the rod guide assembly 38, which closes the upper end of the pressure tube 32. The end of the piston rod 36 opposite to the piston assembly 34 is secured to a sprung portion of the vehicle 10 via an upper mount assembly 48. The end of pressure tube 32 opposite to the rod guide assembly 38 is closed by an end cap 50 that is connected to an unsprung portion of the vehicle 10. It is also anticipated that the piston rod 36 can be attached to the unsprung portion of the vehicle 10 and the end cap 50 attached to the sprung portion of the vehicle 10.

**[0020]** Referring now to Figures 2 and 3, the air spring assembly 24 of the integrated shock assembly 30 comprises a flexible bladder 52 which is secured to the shock absorber 22 using a retainer 54 and which is secured to the upper mount assembly 48 by a retainer 56. The bladder 52 defines chamber 58 that contains pressurized gas for supporting the body 16 of the vehicle 10. The chamber 58 of the bladder 52 and the lower working chamber 44 of the shock absorber 22 are pressure-dependent on one another through a booster 60.

**[0021]** The booster 60 boosts the air pressure within the lower working chamber 44 of the shock absorber 22. The booster 60 includes a housing 62 and a piston assembly 64 slidably disposed therein. The housing 62 defines a working chamber 66 that is separated into a first working chamber 68, a second

or intermediate working chamber 70 and a third working chamber 72 by the piston assembly 64. The piston assembly 64 includes a large diameter piston 74 slidably disposed in a first section 76 of the housing 62 and a small diameter piston 78 slidably disposed within a second section 80 of the housing 62. The large diameter piston 74 is connected to the small diameter piston 78 by a piston rod 82.

**[0022]** The first working chamber 68 is in fluid communication with the chamber 58 of the air spring assembly 24 through a conduit 84. The intermediate working chamber 70 is in fluid communication with atmosphere through a vent 86. The third working chamber 72 is in fluid communication with the lower working chamber 44 of the shock absorber 22 through a conduit 88. A restrictor 90 is optionally provided to restrict fluid flow through the conduit 84. The restrictor 90 inhibits dynamic interaction between the air spring assembly 24 and the shock absorber 22. A resilient member 92 is optionally provided to influence sliding movement of the piston assembly 64. The resilient member 92 applies a reaction force against the piston assembly 64 as the piston assembly 64 compresses the resilient member 92.

**[0023]** For both the integrated shock assembly 30 and the separate shock absorber 22 and air spring assembly 24, the air pressure within the air spring assembly 24 is lower than the pressure within the shock absorber 22. The booster 60 enables boosting of the air pressure within the shock absorber 22 and adjustment of the power dissipation ability of the shock absorber 22 based on the load of the vehicle 10. As the vehicle load is increased a load force  $F_{LOAD}$  acts

on the air spring assembly 24 until a static state is achieved.  $F_{LOAD}$  increases the pressure ( $P_{ASA}$ ) within the air spring assembly 24.  $P_{ASA}$  acts across the surface area ( $A_{LDP}$ ) of the large diameter piston 74 applying a force ( $F_{LDP}$ ) and inducing movement of the large diameter piston 74. The large diameter piston 74 moves until the static state is achieved.

[0024] As the large diameter piston 74 is caused to move, the small diameter piston 78 correspondingly moves. The pressure ( $P_{LWC}$ ) within the lower working chamber 44 acts across the surface area ( $A_{SDP}$ ) of the small diameter piston 78. Thus, prior to achieving the static state, the small diameter piston 78 is caused to move and  $P_{LWC}$  increases. Additionally, as the large diameter piston 74 moves, it contacts the resilient member 92, compressing the resilient member 92. Upon achieving the static state the forces are balanced across the piston assembly 64 to provide:

$$F_{LDP} = F_{SDP} + F_{RES} \quad (1)$$

where:  $F_{LDP}$  = the force acting on the large diameter piston 74;

$F_{SDP}$  = the force acting on the small diameter piston 78, and

$F_{RES}$  = the force acting on the large diameter piston 74 by the resilient member 92.

The pressure forces can be expressed in terms of  $P_{ASA}$  and  $P_{LWC}$  and the resilient member force in terms of its spring rate ( $k$ ) to provide:

$$P_{ASA} A_{LDP} = P_{LWC} A_{SDP} + kx \quad (2)$$

where:  $x$  = the distance the resilient member 92 has been compressed.



**[0025]**  $A_{LDP}$  can be expressed as a multiple of  $A_{SDP}$ . This relationship is expressed as:

$$A_{LDP} = nA_{SDP} \quad (3)$$

where:  $n > 1$ .

Combining equations 2 and 3 provides:

$$P_{LWC} = nP_{ASA} - \frac{kx}{A_{SDP}} \quad (4)$$

where:  $\frac{kx}{A_{SDP}}$  = the pressure relieved by  $F_{RES}$ .

Thus, the booster 60 multiplies  $P_{ASA}$  by the factor  $n$  and applies that pressure to the lower working chamber 44 as  $P_{LWC}$  minus the pressure relieved by  $F_{RES}$ .

**[0026]**  $P_{ASA}$  can be expressed as a function of  $F_{LOAD}$  according to the following:

$$P_{ASA} = \frac{F_{LOAD}}{A_{ASA}} \quad (5)$$

where:  $A_{ASA}$  = the total surface area of the bladder 52 over which  $P_{ASA}$  acts.

Equation 5 can be integrated into equation 4 to provide:

$$P_{LWC} = n \frac{F_{LOAD}}{A_{ASA}} - \frac{kx}{A_{SDP}} \quad (6)$$

Equation 6 illustrates that  $P_{LWC}$  is a proportional to  $F_{LOAD}$  and therefore, the dampening power of the shock absorber 22 is dependent on  $F_{LOAD}$ .

**[0027]** Referring now to Figure 4, an alternative booster 60' is illustrated. The booster 60' adapts the air pressure within the chamber 58 of the air spring assembly 24 and the air pressure within the lower working chamber 44

of the shock absorber 22. The booster 60 includes a housing 62' and a piston 64' slidably disposed therein. The housing 62' defines a working chamber 66' that is separated into a first working chamber 68' and a second working chamber 70' by the piston 64'. A resilient member 92' is disposed within the first working chamber and biases the piston 64'. More specifically, the resilient member 92' maintains the piston 64' in a neutral position when the vehicle 10 is unladen.

**[0028]** The first working chamber 68' is in fluid communication with the chamber 58 of the air spring assembly 24 through the conduit 84. The second working chamber 70' is in fluid communication with the lower working chamber 44 of the shock absorber 22 through the conduit 88. The restrictor 90 is optionally provided to restrict fluid flow through the conduit 84. The restrictor 90 inhibits dynamic interaction between the air spring assembly 24 and the shock absorber 22.

**[0029]** In the unladen condition, the pressures and forces are static. This provides a force balance across the piston, which can be expressed as:

$$F_{FDD} = F_{ASA} + F_{RES} \quad (7)$$

where:  $F_{FDD}$  = the force acting on the piston 64' resulting from  $P_{LWC}$ ;

$F_{ASA}$  = the force acting on the air spring assembly 24; and

$F_{RES}$  = the force acting on the large diameter piston 74 by the resilient member 92.

Thus, when the vehicle is unladen, the pressure in the air spring assembly 24 is lower than the pressure in the lower working chamber 44. As the vehicle is laden,  $P_{ASA}$  increases, resulting in movement of the piston 64' until a new static

state is achieved. The force balance of the new static state is similarly expressed as:

$$F_{FDD} = F_{ASA} + F_{RES} \quad (8)$$

Assuming the piston 64' has moved enough where the resilient member 92' is no longer acting on the piston 64', equation 8 can be expressed as:

$$F_{FDD} = F_{ASA} \quad (9)$$

[0030] Equation 9 can be rewritten in terms of  $P_{ASA}$  and  $P_{LWC}$  to provide:

$$P_{LWC} A_{PISTON} = P_{ASA} A_{PISTON} \quad (10)$$

where:  $A_{PISTON}$  = the surface area of each side of the piston 94'.

As can be seen, when the vehicle is laden,  $P_{LWC}$  is equal to  $P_{ASA}$ .

[0031] Implementation of the boosters 60 and 60' between the air spring assembly 24 and the shock absorber 22 enables a load dependent shock absorber 22. More specifically, the power dissipated by the shock absorber 22 is a function of the static pressure therewithin. The air pressure within the air spring assembly 24 is proportional to the load of the vehicle 20. The booster 60 enables use of the air pressure within the air spring assembly 24 to adapt the pressure within the shock absorber 22.

[0032] The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.